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AUTHOR(S) – R. E. McGaughy

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ABSTRACT

This memorandum describes, in broad terms, the general types of biological science activity which would be meaningful in a six-man, two-year earth orbiting multi-disciplinary space station. The rationale for doing biology experiments on such a mission is discussed and the demands on crew time and skills, as well as on the spacecraft resources, are outlined in a manner consistent with those imposed by the other disciplines.

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955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D.C. 20024

SUBJECT: Bioscience Subsequence in a Multi-Disciplinary Space Station. Case 720.

DATE: December 27, 1968

FROM: R. E. McGaughy

TECHNICAL MEMORANDUM

I. INTRODUCTION

This memorandum discusses the biological experiment activity which might be carried out on a six-man, two-year earth-orbital space station whose general characteristics are outlined in a memorandum by G. T. Orrok (Ref. 1). Major emphasis will be placed on the general types of biological science activity which would be meaningful in the space station rather than a detailed description of each crew member's activity throughout the mission. All of the scientific activities are bounded by the sleep-eat-work schedule described by S. L. Penn (Ref. 2) and referred to as the Personal Maintenance Subsequence.

Rationale for Earth Orbital Biology Experiments

There are several reasons for doing biology experiments in earth orbit.

1. The unique environment of an earth-orbiting satellite can contribute to our knowledge of basic biological processes. Experiments in zero gravity are needed to test theories of the nature of gravity perception in plants and geotropism in roots and stems. In addition, measuring the growth of embryos in a reduced gravity environment might clarify the nature of cellular and tissue specialization during animal development. Since earth satellites experience none of the earth's normal 24-hour (circadian) periodicities of gravity fields, magnetic fields and light intensity, experiments in earth orbit might be useful in discovering the mechanism of circadian periodicities of the metabolism and activity of living systems.

2. Experiments on animals in space can help us understand the process of human adaptation to the space environment. It is possible to measure a greater variety of physiological and behavioral parameters on animals than on man, and these measurements could help us understand the process of adaptation to zero-G conditions. Animals are also useful for testing potential countermeasures (e.g., drug treatments) against the adverse effects experienced by man in

the space environment. In preparing for manned planetary flight, where emergencies must be met on board the spacecraft rather than going to the ground for help, man should develop the skills of surgery in the weightless environment. Therefore, surgical practice on animals in space becomes desirable.

3. An earth-orbiting space station is an ideal platform for testing techniques for the detection of extraterrestrial life. This has two aspects: (a) remote sensing of life on Earth, and (b) laboratory analysis of terrestrial soils and meteoroids collected in space. Zero-gravity techniques in sample handling and experimentation under sterile conditions must be developed if man is to analyze soil samples from a planetary landing or fly-by.

In addition to these explicit reasons for performing earth-orbital biology experiments, it is always possible that the experiments will turn up surprises where we are not looking for them. This is especially true for the proposed group of experiments which investigate the effects of zero-gravity on a wide range of plants and animals. From a long-range viewpoint, this serendipity rationale is an important factor in the development of new capabilities.

II. HARDWARE NEEDED FOR BIOLOGY EXPERIMENTS

The Douglas Biotechnology Laboratory Study (Ref. 3) lists the equipment needed to carry out most of the biology experiments referred to above. This list, which omits exobiology-related equipment, includes life support facilities for biological specimens and laboratory instruments for analyzing metabolism, growth, tissue structure, and chemistry of body fluids.

It should be pointed out that exobiology activities require, in addition to a small amount of special equipment, their own sterile working area of the spacecraft. This area must be completely isolated from all sources of terrestrial contamination for the entire duration of the flight. The animal surgery and some laboratory analyses also require a sterile working area, but the latter area can be sterilized immediately before the experiment is performed, and therefore requires no unusual design effort.

III. DESCRIPTION OF BIOLOGICAL EXPERIMENT ACTIVITY

Table I (from Hilchey and Mason, Ref. 4, p. 8) shows the general types of activity for which man is needed in performing space biology experiments. It emphasizes the progressive degree of involvement which occurs as scientific abilities are gradually improved in space. By the time the two-year space station is launched, we expect that the astronauts will be at about level C, where they will be making significant contributions as trained biology technicians.

In Figure 1, the biological science activities of the space station are described as a series of modes, each with its own requirements of crew time and spacecraft resources. By including an "unattended" mode (Mode A), we emphasize that the specimens (e.g., bacteria, plants, animals) are continually being supported by the spacecraft life-support equipment, but that crew time is not needed to keep them alive. The film requirements allow for time-lapse photography of growing tissue at the rate of one picture every five minutes. The automatic tape recording of data allows for 10^4 bits per day for each of ten experiments. The power needed for conducting all of the biology experiments listed in the recent "Experiment Program for Manned Orbital Workshops" (Ref. 5) is about 1050 watts.

Mode B (biological housekeeping) includes a major part of the routine bioscience activity described in Table I. It is during this time that the specimens will be checked for integrity, growth patterns observed, samples collected and preserved, and specimens fed.

In Mode C the bioscience specialist performs laboratory analysis of various samples (animal body fluids, tracer chemistry in tissue cultures and bacteria, staining of tissue for microscope examination, photomicrography, bacterial growth analysis, survival studies of terrestrial organisms in space, etc.). The time devoted to these tasks depends strongly on the skills and interest of the scientists on board, and the figure of 4-8 hours per week should be regarded only as a preliminary estimate.

The animal surgery (Mode D) and exobiology (Mode E) activities are described as separate modes because they each require their own block of time, use their own sterile areas of the spacecraft, and require unique crew skills. For example, the animal surgery experiments are specifically designed for a physician, who might not be trained to identify competently the types of micro-organisms in soil samples.

If one of the biological specimens becomes ill, as described in Mode F, then a crew member could be occupied with surveillance and treatment and become unavailable for other tasks. In this mode, as in all of the bioscience modes, no special communication or power load is imposed on the spacecraft operational systems.

IV. SUMMARY

This memorandum has outlined, in broad terms, the general types of biological science activity which would be meaningful in an earth-orbiting space station. We have discussed the way in which these activities demand crew time and skills as well as spacecraft resources. Figure 1 summarizes these demands in a form compatible with those of other disciplines.

The author would like to thank S. L. Penn and G. T. Orrok for helpful comments concerning the organization of Figure 1.

R. E. McGaughy

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R. E. McGaughy

Attachments
Table I
Figure 1

REFERENCES

1. "Introduction to a Study of Operations on a Multi-Disciplinary Space Station," Orrok, G.T., Bellcomm TM-68-1011-11, December 27, 1968.

2. "Mission Sequence Plan for a Multi-Disciplinary Earth Orbital Space Station - A Preliminary Report," Penn, S.L., Bellcomm TM-68-1011-9, December 27, 1968.

3. "Requirements Study for a Biotechnology Laboratory for Manned Earth Orbiting Missions," Douglas Missile and Space System Division, July, 1968.

4. "Contribution of Man to Space Biology Flight Programs," Planning Source Document for the Space Biology Program Memorandum, J.D. Hilchey, J.A. Mason, 1968.

5. "Experiment Program for Manned Orbital Workshops," Payloads Directorate, OMSF, August 14, 1968 (Draft).

TABLE I

JOB DESCRIPTIONS FOR
FIVE REASONABLE ALTERNATIVE ASTRONAUT ROLES
IN ORBITAL SPACE BIOLOGY RESEARCH

ALTERNATIVE	DUTIES
O	Return logistics (brings back experiment package)
A	As above, plus: Monitors conditions of experiment as a whole Logs and/or transmits monitored records
B	As above, plus: Deploys experiments Starts up experiments Preventive maintenance Repairs or realigns Specimen removal and preservation Termination of experiments
C	As above, plus: Executes simple Survey Research Program Simple experiment manipulations Simple observations Reports significant events to ground P.I. Initiates simple repeat or follow-on experiments with reusable/adaptive equipment
D	As above, plus: As P.I., or member of P.I. team As professionally qualified and experienced specialist initiates, revises, redirects: Series of related experiments To further a complex, indepth research program To assure maximum scientific worth of program

MODES / PROPERTIES	A SPECIMENS UNATTENDED	B BIOLOGICAL HOUSEKEEPING	C LABORATORY ANALYSIS	D ANIMAL SURGERY	E EXOBIOLOGY	F SPECIMEN ILLNESS
I. TIME: a) DURATION, REPETITIONS, USE OF CREW b) CONSTRAINTS	a) DURATION IS CONTINUOUS CREW NOT NEEDED	a) TWO MAN-HOURS PER DAY	a) ONE MAN 4 TO 8 HOURS PER WEEK IN 2 TO 3 HOUR SESSIONS	a) TWO MEN, 3 HOURS, 3 TO 4 TIMES DURING MISSION	a) ONE MAN, 8 HOURS PER DAY, 3 TO 4 TIMES DURING MISSION	a) ANIMALS MAY NEED CONTINUOUS SURVEILLANCE IF SERIOUSLY INJURED. ONLY ONE PERSON NEEDED
II. ACTIONS & FUNCTIONS: AGENTS: CREW INTEGRATED MEDICAL & BEHAVIORAL LABORATORY MEASUREMENT SYSTEM (IMBLMS) MISSION CONTROL CENTER (MCC) PRINCIPAL INVESTIGATOR (PI)	IMBLMS AUTOMATICALLY RECORDS DATA	CREW FEEDS ANIMALS, CLEANS CAGES, VERIFIES PROPER EXPERIMENT FUNCTIONING, COLLECTS SAMPLES, INITIATES AND TERMINATES EXPERIMENTS, CHANGES CULTURE MEDIA, PHOTOGRAPHS CULTURES, PRESERVES TISSUE FOR LATER ANALYSIS. AUTOMATIC RECORDING CONTINUES AS IN MODE A FOR EXPERIMENTS NOT BEING SERVICED BY CREW	CREW CHEMICALLY ANALYZES URINE, FECES, BLOOD, FROM ANIMALS USING IMBLMS WITH MCC AND PI. (CREW MAY CONSULT WITH MCC, PI)	CREW PERFORMS SURGICAL OPERATIONS, USING IMBLMS STERILE AREA OF WORKSHOP NEEDED	CREW CHEMICALLY ANALYZES TERRESTRIAL SOIL SAMPLES AND METEOROIDS FROM SPACE USING SPECIAL STERILE LABORATORY AREA AND IMBLMS. CREW CONSULTS WITH MCC AND PI	CREW DISPOSES OF DEAD ANIMALS AND PLANTS, CARES FOR SICK SPECIMENS
III. INFORMATION FLOW: a) INFORMATION REQUIRED b) ACTIVE LINKS c) DATA PRODUCED 1) FILM (TYPE #FRAMES OR FEET, WEIGHT TO BE RET'D QUARTERLY, ETC.) 2) TAPE (BIT RATES-MAXIMUM SUSTAINED, PEAK, AVG.; SPECIAL DUMP REQ'S.) 3) REAL TIME TRANSMISSION	a) PHYSIOLOGICAL AND CABIN ENVIRONMENT DATA b) NONE c) 1) ABOUT 300 EXPOSURES (MAX.) PER DAY 2) 10^5 BITS/DAY 3) NONE	a) AS IN MODE A b) OWS-MCC-PI OCCASIONALLY c) 1) 10 EXPOSURES PER DAY 2) LOG BOOK DATA 3) VOICE CHANNEL NEEDED	a) RESULTS OF TESTS b) OWS-MCC-PI c) 1) 25 EXPOSURES PER DAY 2) LOG BOOK DATA 3) VOICE CHANNEL	a) CREW EXPERIENCE WITH MANUAL SKILLS b) OWS-MCC-PI c) 1) NONE 2) LOG BOOK DATA 3) VOICE CHANNEL	a) b) c) $\}$ AS IN MODE C	a) DESCRIPTION OF SYMPTOMS, RESULTS OF TESTS b) OWS-MCC-PI c) VOICE CHANNEL
IV. RESOURCES REQUIRED: a) POWER b) OTHER (BESIDES ORDINARY CONSUMABLES, LIKE FOOD, O_2, & WATER.)	a) 1,050 WATTS FOR LIFE SUPPORT, PLUS 100 WATTS (CONTINUOUS) SUPPLIED BY IMBLMS	a) AS IN MODE A	a) AS IN MODE A b) CHEMICALS FOR ANALYSIS	a) AS IN MODE A b) SURGICAL SUPPLIES	a) AS IN MODE A b) SPECIAL CHEMICALS AND STERILE SUPPLIES	a) AS IN MODE A b) DISPOSABLE BAGS, DRUGS AND OTHER MEDICAL SUPPLIES
V. TRANSITIONS: a) SCHEDULED (NOMINAL) b) UNSCHEDULED (CONTINGENCIES)	a) FOR SCHEDULED ACTIVITIES, GO TO MODE B, C, D, E, AS APPROPRIATE b) IF SPECIMENS BECOME ILL, INJURED, OR NON-FUNCTIONAL, GO TO MODE F	a) WHEN BIOLOGICAL HOUSEKEEPING IS FINISHED, GO TO MODE A	a) WHEN LABORATORY ANALYSIS IS FINISHED, GO TO MODE A b) IF ANALYSIS SHOWS A SICK ANIMAL OR PLANT, GO TO MODE F	a) WHEN ANIMAL SURGERY IS FINISHED, GO TO MODE A b) IF ANIMALS DIE, GO TO MODE F	a) WHEN EXOBIOLOGY ANALYSIS IS FINISHED, GO TO MODE A	a) WHEN SPECIMENS ARE CURED OR DISPOSED OF, GO TO MODE A

FIGURE 1 - BIOSCIENCE SUBSEQUENCE